787

Effect of Application of Heat on Tomato Juice Color[a,b]

AMIHUD KRAMER AND A. A. EL-KATTAN
Department of Horticulture, University of Maryland, College Park

The effect of heat application on the loss of color in tomato juice was found to proceed in accordance with the equation: Color loss $= \log \frac{Ts}{525}\left(\frac{RT-120}{40}\right)$ where color loss is in terms of the U. S. Department of Agriculture scoring system, Ts refers to temperature summations in terms of degrees F., above 140 times seconds, and RT is the retort temperature.

Color is the most important single factor involved in the quality evaluation of tomato products *(8)*. With the recent development of high temperature and tubular sterilization methods the processor has the opportunity of selecting from a wide array of heat sterilization procedures the one most satisfactory for his purpose. Since maximum color retention is extremely important, the processor should have at his disposal some means of predicting just how a given procedure will affect the color of the finished product.

This study was undertaken in an effort to find the basic law governing the extent of color loss resulting from the application of heat to tomato products.

It has been observed generally that the color of tomato juice deteriorates as a result of heat processing. These observations have been supported by experimental studies by MacGillivray *(6)*, and more recently by Robinson *et al. (7)*, Friedman *et al. (3)*, and others *(5, 10)*. Blumer *et al. (2)* reported that when equivalent sterilizing values were used, there were no color differences between samples of juice flash sterilized at temperatures varying from 250 to 270° F. However, some statements not substantiated by experimental data, were made to the effect that higher sterilization temperatures resulted in higher color losses, although there is a general impression that high temperature short time processes favor color retention for heat processed foods as a general rule.

MATERIALS AND METHODS

In order to obtain rapid heat transfer into the tomato juice sample, a heat exchange cell was fabricated (Figure 1) from 1/16 inch stainless steel tubing. A 6.2 cm. outside diameter tube was nested into a 8.2 cm. tube, so that with a small amount of milling the distance between the two tubings was 8 mm. The length of the tubing was 12 cm. Thus the volume of the cell which consisted of the space between the tubes could contain a sample of approximately 200 ml. none of which was more than 4 mm. from the surface. Temperatures were recorded with a Taylor recording instrument equipped with a transmitter to eliminate temperature lag. Results with this recorder were checked against a similar cell equipped with thermocouples, and temperatures determined with a potentiometer. The assembled cell containing the sample charge and the temperature measuring element was placed in an oil bath where the temperature could be controlled to ±.5° C. The temperature of the oil bath was set at 10° F. intervals beginning with 160 to 285° F., which was the maximum temperature at which the oil bath functioned accurately. The oil in the bath, and the heat exchange cell were kept under constant agitation in order to facilitate rapid and uniform heat transfer. In one series of experiments, the cell was held in the oil bath until the bath temperature was reached in the sample. In another series, the cell was held in the bath for different periods of time after maximum temperature was reached in the sample. Upon removal from the bath, the cell was immediately placed in one of three cooling tanks which consisted of (a) tap water, (b) ice water, and (c) acetone cooled with dry ice. Altogether 291 heating-cooling curves were obtained in this manner (Figure 2). The tomatoes used for this study were of the Rutgers variety, grown at the Plant Research farm of the University of Maryland. Sound tomatoes of good color were selected at all times; however, since the studies extended over the entire harvesting season, from August to October, 1952, it was impossible to obtain tomatoes of identical

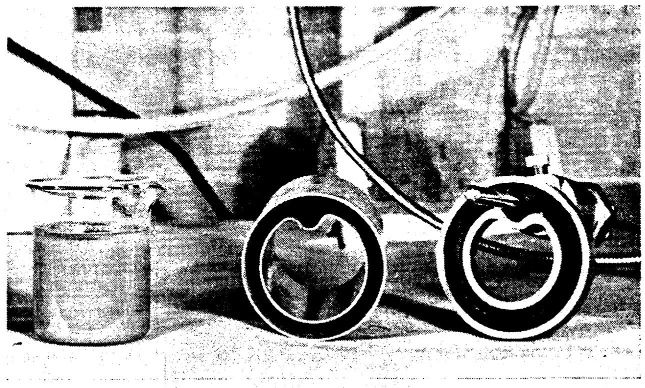

Figure 1a. Details of the heat exchange cell.

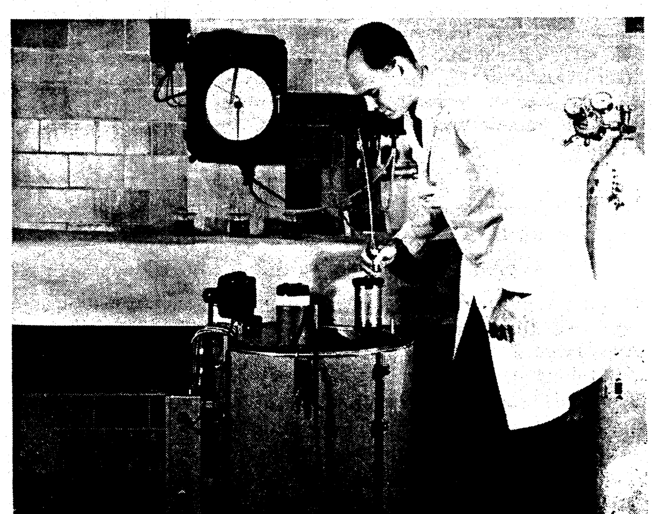

Figure 1b. Assembled heat exchange cell about to be inserted in the oil bath.

[a] Presented at the Thirteenth Annual Meeting of the Institute of Food Technologists, Boston, Massachusetts, June 23, 1953.

[b] Scientific Publication No. A404, Contribution No. 2432 of the Maryland Agricultural Experiment Station (Department of Horticulture). A report of work done under contract with the United States Department of Agriculture, and authorized by the Research and Marketing Act of 1946. The contract is being supervised by the Eastern Regional Research Laboratory of the Bureau of Agricultural and Industrial Chemistry.

color throughout the season. The results were therefore reported in terms of color loss as compared to the original raw tomato juice color rather than in terms of the actual color of the heated juice.

The tomatoes were cored and trimmed, and juiced in a miniature laboratory pulper and finisher, using a .028" screen. A sample was removed for immediate color analysis, and the remainder was used as charges in the heat exchange cell in order to obtain the heating-cooling curves described above.

Color was determined by the use of the Hunter color and color difference meter *(4)* which was first standardized with a tomato red color title. The "a" and "b" Hunter values were then trans-

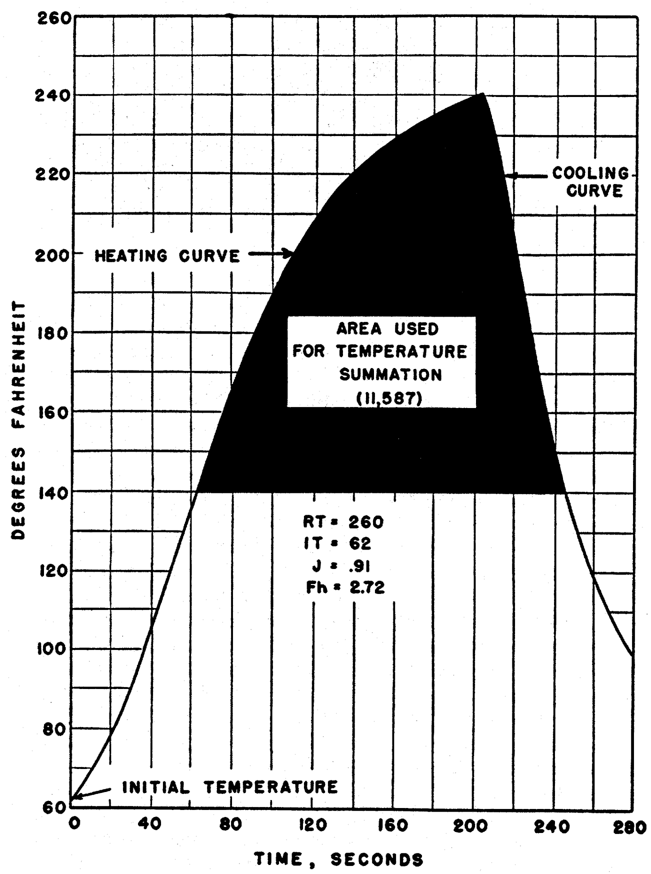

Figure 2. A heating-cooling curve, showing area used for obtaining the temperature summation. In this instance, juice with initial temperature of 62° F. (IT) was placed in heat exchange cell, and the cell immersed in the oil bath held at 260° F. (RT). The cell was removed from the oil bath when the temperature of the juice reached 240° F. (top of heating curve) and cooled in ice water (cooling curve). The actual temperature summation for this sample was 11,587 second-degrees.

formed to the equivalent U. S. score for canned tomato juice in accordance with the following equation:

$$\text{U. S. color score} = 32.6 + .682a - 1.678b$$

A nomograph for obtaining U. S. color scores in accordance with this equation, is presented as Figure 3. The color loss resulting from any given application of heat was then obtained by subtracting this U. S. score equivalent obtained for the heated sample from that obtained on the original unheated juice.

The area under the heating-cooling curve was obtained by the use of a planimeter, and reported in terms of seconds degrees Fahrenheit summations, above a given temperature base. Thus with a baseline set at 140° F., one second at 141° F. was equivalent to one temperature summation (second-degree) while one second at 240° F. was equivalent to 100 temperature summation, etc.

DISCUSSION OF RESULTS

In order to develop a single expression of the relation between the heat treatments and color loss, it was neces-

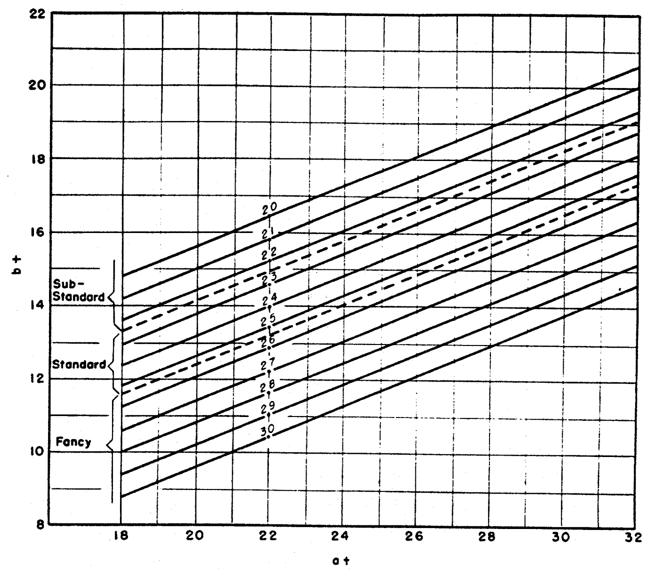

Figure 3. U. S. grades for tomato juice color in terms of Hunter a and b values.

sary to determine the nature of the correlation between these two factors, so that the regression line could then be used to predict the effect of any given heat application on color loss. Before such a correlation could be calculated it was necessary to have single values for each of these factors. Fortunately a method was available for converting Hunter color and color difference values into a single U. S. color grade equivalent value *(4)*. This was done, as described above.

For converting the heating-cooling curves to single values, the temperature summation method was employed. This method is in common use in evaluating the effect of temperature on plant growth *(9)*. Here the first problem is to establish the temperature "base line" —that is, the lowest point on the temperature scale which may have a measurable effect on the product. For plant growth, this point would be the lowest temperature below which there is little measurable growth, whereas in the present study, it would of course, be the lowest point below which there is no measurable color loss.

This point on the temperature scale may be determined by correlating the dependent factor, in this case color loss, with temperature summations as calculated from different base lines. The results shown in Table 1 indicate that the highest correlation was obtained using 140° F. as a base line.

TABLE 1
Correlations between color loss and temperature summations calculated at different base lines (bath temperatures 230-285° F.)

Base line, ° F.	Correlations	
	Linear	Logarithmic
120	.895	.927
140	.909	.942
160	.893	.921

It was therefore concluded that 140° F. is the highest temperature at which there is no appreciable loss in tomato juice color. The data in Table 1 also indicate that the relationship of color loss to temperature summations is logarithmic rather than linear. Although the best correlation of .942 is remarkably high, considering the fact that different batches of tomatoes were used, it was nevertheless apparent from examination of the data, that as the bath temperatures were increased, color loss was greater for the same temperature summation. This is illustrated for several bath temperatures in Figure 4. Correlations were therefore calculated for individual bath temperatures, with the following results:

TABLE 2
Correlations between color loss and temperature summations for individual bath temperatures

Bath temperature, ° F.	Correlation
230	.979
240	.965
250	.995
260	.979
270	.982
285	.970

Since all the individual correlations in Table 2 were significantly higher than the correlation of .942 for the combined data, separate regression lines were constructed for each temperature bath. Then with only slight adjustments for equal spacings, Figure 5 was constructed, showing the overall effect of heat application to color loss. This relationship may be expressed by the following equation:

$$\text{Color loss} = \text{Log}\,\frac{\text{Ts}}{525}\,\frac{(\text{RT} - 120)}{40}$$

Where color loss is expressed in terms of units of the U. S. grading system, Ts is temperature summations above 140° F., and RT is the retort temperature, being in this case, the temperature of the oil bath.

In order to use Figure 5 or the equation, it is necessary to know the temperature of the medium (retort, tube, bath, etc.) and to have a complete heating-cooling curve (see Figure 2) from which the temperature summation may be calculated. This may be done rather laboriously by obtaining the sum of the seconds included under the curve for each degree above 140° F. Where extreme accuracy is not necessary, intervals greater than one degree or one second may be used. Heat summations may be obtained accurately and more rapidly by the use of a planimeter.

In order to utilize these curves to compare color loss that might be expected when different retort temperatures are used to obtain equivalent sterilization values, Ball's equations *(1)* were used on some of the heat penetration data obtained with the heat exchange cell. The results superimposed on Figure 5 show that there is little difference in the color of the tomato juice heated at different bath temperatures, although there is some tendency for the color loss to be greater as the temperature of the bath is increased. Similar results were obtained when temperature summations were estimated from the data of Blumer *et al. (2)*.

These results must be presented in terms of temperature summations rather than in terms of seconds or minutes at a given retort temperature because heat penetration in different containers varies; however, where internal temperature is equal to the retort temperature, color loss may be read directly from Figure 6, where minutes at the retort temperature are plotted against color loss.

The extremely high correlations of approximately .98 between color loss and temperature summations for any given retort temperature indicate that deterioration of tomato juice color during processing is a direct func-

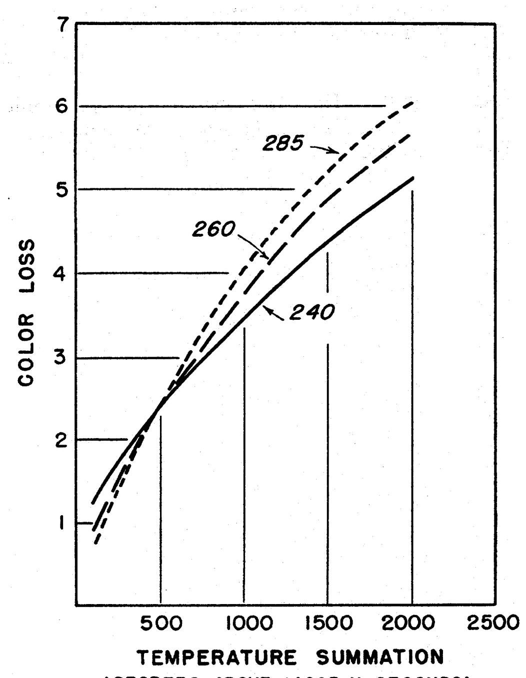

Figure 4. Regression curves showing the relation of temperature summations to color loss at specific bath temperatures.

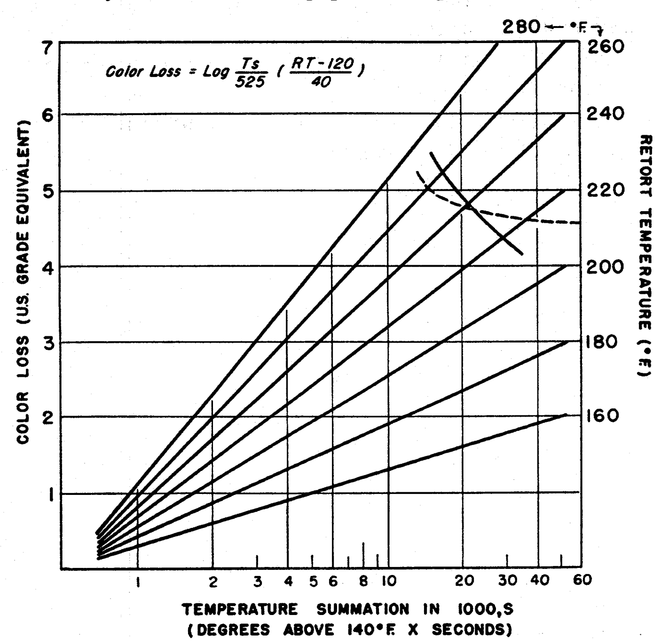

Figure 5. Relation of temperature summations to color loss at different bath temperatures. Broken line indicates predicted color loss resulting from heating at different retort temperatures for periods of time adequate for sterilization assuming an F_o of 0.7 for tomato juice.

tion of temperature. Rapidity of cooling apparently has no effect beyond its contribution to a reduction in the temperature summation. If some enzyme or enzymatic system were involved, it might be expected that a very

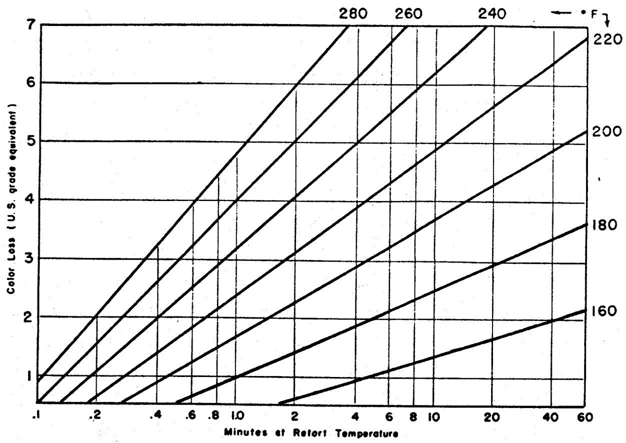

Figure 6. Effect of heating at different bath temperatures on color loss where juice temperature is the same as retort temperature.

rapid passage through some specific temperature zone would have an effect on color loss; however, no such evidence was found in the wide array of come-up and cooling curves obtained, and color loss in all cases proceeded along straight logarithmic lines.

No other factors were found to alter this conclusion that color loss is entirely a temperature function. In contrast to other reports *(6)* variations in atmosphere or pH had no effect on the rate of color loss. These results will be the subject of another paper.

Although these results provide a conclusive picture, several questions remain unanswered and should be the subject of additional work.

(a) Do heating media other than oil baths have a similar effect on color loss?

(b) What is the effect of two or more heating temperatures on color loss?

It is common practice to preheat tomato juice to from 160 to 205° F. before sterilization at higher temperatures. Since color loss is a logarithmic function, every increment in heating time results in a proportionally smaller increment of color loss. For example, tomato juice is preheated at 210° F. to 180° F., and cooled to 165° F. before processing at 260° F. The heat summation for the preheating curve is calculated at 5,000, and for the processing curve also at 5,000. Consulting Figure 5, we obtain a color loss of 2.2 for the preheating period. It is then logical to assume that the process heating at 260° F. would result only in a further color loss between 5,000 and 10,000 which on the 260° F. line would be 4.5–3.4, or 1.2 rather than a color loss of 3.4 which would be obtained if the 5,000 degree summations were taken from the 260° F. line between 0 and 5,000. The validity of such a procedure however, remains to be determined.

LITERATURE CITED

1. Ball, C. O. Mathematical solution of problems on thermal processing of canned foods. *Public Health,* 1 (2) 15 (1928).
2. Blumer, T. E., Parrin, F. W., and Peterson, G. T. Effect of sterilization temperatures on color of tomato juice. *Bull. 28,* Research Div. Continental Can Company, Chicago (1952).
3. Friedman, M. E., Marsh, G. L., and Mackinney, G. On color in tomato products. *Food Technol.,* 6, 395 (1952).
4. Kramer, A. Memorandum to processors of tomato products. Md. Agr. Exper. Sta. (Mimeo. Pbl.) (October, 1952).
5. Kramer, A. (Data presented before a meeting at the National Canners Association, Washington, D. C., December, 1951.)
6. MacGillivray, J. H. Tomato color as affected by processing temperatures. *Proc. Amer. Soc. Hort. Sci.,* 29, 353 (1931).
7. Robinson, W. B., Ransford, J. R., and Hand, D. B. Measurement and control of color in the canning of tomato juice. *Food Technol.,* 5, 514 (1951).
8. United States Department of Agriculture, Standards for grades of canned tomato juice. (Mimeo. Pbl.), Washington, D. C.
9. Walls, E. P. Predicting maturity dates of canning crops from temperature records. *Proc. Canners', Freezers', Fieldmens' Short Course.* Md. Agr. Exp. Sta. *Misc. Pub. 122* (1950).
10. Younkin, S. G. (Data presented before a meeting at the National Canners Association, Washington, D. C., December, 1951.)